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Overview of Incineration Performance

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OVERVIEW OF INCINERATION PERFORMANCE

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ABSTRACT

During the early 1980's the Office of Research and Development, EPA conducted field evaluations at eight hazardous waste incinerators, eleven industrial boilers, and eight industrial furnaces to characterize their emissions and assess the performance of these facilities to destroy hazardous wastes. The results of these studies plus trial burn data submitted by 14 RCRA applicants are summarized and compared with the 1982 hazardous waste incinerator regulations and the proposed (5-6-87) industrial boiler and industrial furnace regulations.

INTRODUCTION

Historically, the management of hazardous wastes has occasionally employed relatively inexpensive and improper disposal practices. This has led to numerous environmental catastrophes such as Love Canal, New York; "Valley of the Drums", Bullet County, Kentucky; and Times Beach, Missouri. As a result, substantial action has been taken by Congress during the past decade to prevent similar problems in the future and to begin cleaning up numbers of abandoned or poorly designed and polluting sites.

The most significant of these actions has been the passage of four laws. The first was the Resource Conservation and Recovery Act of 1976 (RCRA) which defined and identified hazardous wastes and provided for its control during storage, transport, treatment, and disposal. Secondly, the passage of the Comprehensive Environmental Response Compensation and Liability Act of 1980 (CERCLA) established a national fund (Superfund) to clean-up uncontrolled waste sites created by poor disposal practices. Subsequently, both of these Acts were reauthorized and amended.

The Hazardous and Solid Waste Amendments of 1984 (HSWA) reauthorized and amended RCRA and specified a strict timeline for restricting untreated hazardous waste from land disposal. The 1986 Superfund Amendments and Reauthorization Act (SARA) reauthorized the Superfund program and greatly expanded the provisions and funding of the initial Act. SARA also emphasized the need to select clean-up technologies that will result in a permanent, significant decrease in the toxicity, mobility, or volume of hazardous materials.

Treatment options which might be considered for a particular application include deep-well injection, landfill, chemical stabilization/solidification, physical/chemical/biological treatment, and thermal destruction. Of these, thermal destruction possesses some highly desirable characteristics. It permanently destroys toxic organic contaminants and generates a significantly reduced volume of residual waste which must be managed. In addition, energy can be recovered in certain applications. One of its major disadvantages is its cost, that is, it is almost always the most expensive alternative. This is illustrated on Figure 1 which gives a current range of disposal costs for the various options.(1) As can be seen, incineration easily can be an order magnitude higher than some of the other alternatives.

In addition to costs, the incineration of hazardous waste is not without problems. No technology currently exists to accurately monitor all emissions on a real time basis and some skepticism exists concerning its safety and effectiveness. The issue of accidents, spills, and mismanagement once a permit is issued are often major community concerns, and the siting of new facilities has also proven extremely difficult.

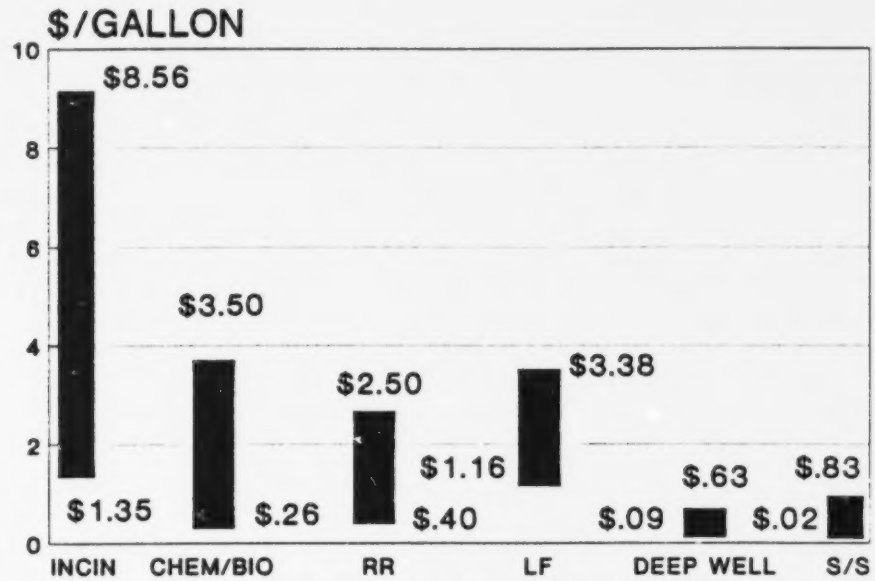

Figure 1. Range of disposal costs by technology.

Note: INCIN = Incineration
CHEM/BIO = Chemical and/or Biological Treatment
RR = Resource Recovery
LF = Landfill
S/S = Chemical Stabilization/Solidification

The thermal destruction of organic constituents is an intensive oxidation process. In an ideal system, organic waste materials composed of carbon, oxygen and hydrogen are converted to carbon dioxide (CO_2) and water vapor (H_2O). Adequate air pollution control equipment (APCE) is employed which effectively cleans the exhaust gases and the resulting ash is rendered inert by the thermal process. However, the ideal is never completely attained. As a result, some organics are not completely destroyed, APCE is not 100% effective, and ash can be contaminated with heavy metals and organics. While all hazardous waste incinerator emissions are important, to date the major environmental concerns have centered on:

- Emissions of organic compounds which can be categorized as unreacted components of the waste and products of incomplete combustion (PICs).
- Emissions of haloacids and halogen gases formed by the burning of waste containing halogenated compounds. For example, HCl and small amounts of chlorine (Cl_2) are formed from the incineration of chlorinated waste components.
- Emission of metals and particulates.

In addition, residual metals in the ash are of concern and all solid and liquid waste streams must be properly managed.

Until recently there was limited data concerning the efficiency of hazardous waste thermal destruction devices and pollutant emissions. However, during the past few years much information has been collected on the subject by EPA research efforts and trial burns conducted by owners of hazardous waste incinerators as part of their Part B application requirements for obtaining a full RCRA operating permit. This paper addresses these concerns primarily by examining the results of test burns conducted at 22 full-scale stationary incinerators, 8 industrial furnaces, and 11 industrial boilers. Fourteen of the incinerator tests were trial burns conducted by the facility owners. All other tests were conducted by EPA. Data from these tests have been summarized in an EPA report, "Permit Writer's Guide to Test Burn Data - Hazardous Waste Incineration" (2) and discussed by Oppelt (3).

REGULATIONS

On June 14, 1982 EPA promulgated the RCRA final incinerator standards.(4) These standards require that the following must be demonstrated before an incinerator will be granted an operating permit:

1) 99.99 percent destruction and removal efficiency (DRE) for each principal organic hazardous constituent (POHC) in the waste feed where:

$$DRE = \frac{Win - Wout}{Win} \times 100$$

where:

Win = mass feed rate of POHC in the waste feed to the incinerator

Wout = mass emissions rate of the POHC released to the atmosphere.

2) 99 percent removal of hydrochloric acid (HCl) or 4.0 lb./h (1.8 Kg/h) HCl emissions, whichever is greater.

3) Particulate emissions must be less than or equal to 180 mg/dscm corrected to 7 percent oxygen in the stack gas. The correction is achieved by multiplying the measurement of particulate concentrations by the following correction factor:

$$\text{Correction Factor} = \frac{14}{(21-Y)}$$

where: Y = measured oxygen percentage in the stack gas on a dry basis as determined by Orsat analysis or equivalent method.

Meeting these requirements is demonstrated by conducting a "trial burn". In addition, the trial burn data provides information for setting limits on operating parameters such as carbon monoxide (CO) level in exhaust, waste feed rate and composition, combustion temperature, combustion gas velocity, allowable variation in design, and other requirements necessary to ensure that regulatory and safety standards are met. POHCs are selected from the RCRA Appendix VIII constituents present in the waste. This list consists of 390 organic and inorganic hazardous compounds which was first published on May 19, 1980 (5) and most recently updated on August 6, 1986 (6). POHCs selected should be difficult to incinerate and present in high concentrations in the waste feed.

On January 19, 1985 the "dioxin rule" (7) was promulgated under the RCRA rules which regulated the incineration of certain wastes containing chlorinated dibenzo-p-dioxins, chlorinated dibenzofurans and chlorinated phenols. Specifically, incineration of these wastes was limited to facilities which can achieve a DRE of 99.9999 for chlorinated dioxins or similar compounds. The incineration of wastes containing polychlorinated biphenyls (PCBs) is controlled under the Toxic Substances Control Act (TSCA) and rules were promulgated (8) in May 1979. Incinerators disposing of this type of waste must achieve a combustion efficiency (CE) of 99.9 percent and meet a number of operating conditions.

The 1982 incinerator standards do not apply to the practice of disposing of hazardous waste as a fuel in industrial boilers and furnaces and at this time this practice is largely unregulated. However, EPA is currently developing regulations which will address this industrial process. On May 5, 1987 EPA proposed rules (9) to control the burning of hazardous waste in boilers and industrial furnaces. These facilities would have to comply with the following:

1. 99.99 DRE for each POHC in the waste feed except for dioxin-containing wastes (F020, F021, F022, F023, F026, and F027) where a DRE of 99.9999 must be met.

2. Risk-based emissions limits for 4 of the 12 Appendix VIII metals which are arsenic, cadmium, chromium, and lead.

3. Risk-based emission limits for HCl.

4. These facilities would be required to operate continuously at a high combustion efficiency by establishing a 100 ppm limit on flue gas carbon monoxide (CO) level corrected to 7 percent oxygen and based on a 60 minute rolling average.

The proposed regulatory approach for boilers and furnaces differs from the incinerator regulations as follows. Under the incinerator regulation, toxic metal emissions are controlled by a particulate matter limit. However, there is concern that under some conditions this may not adequately assure protection of human health. Therefore, the risk-based approach has been proposed for four specific metals. In addition, the incinerator standards control HCl emissions by a technology-based standard as compared to the proposed risk-based standard for industrial boilers and furnaces.

The DRE standard addresses the destruction of toxic organic constituents in the waste, but does not directly control PICs. It is proposed to minimize PICs by requiring industrial boilers and furnaces to operate at a high CE by establishing a limit on the flue gas CO. CE is directly related to CO by the following equation.

$$CE = \frac{\text{Percent } CO_2}{\text{Percent } CO_2 + \text{Percent CO}} \times 100$$

CURRENT PRACTICE

Three types of systems are principally used to thermally destroy hazardous wastes. These are: 1) hazardous waste incinerators specifically designed for this purpose, 2) industrial boilers, and 3) industrial furnaces. The destruction can take place under either oxidative or pyrolytic conditions and typically involves the controlled exposure of the waste to high temperatures [generally in excess of 1800°F (980°C)] for a period of time long enough to destroy the organic constituents and significantly reduce the volume.

Based on a 1983 survey (3), even after recycling and reduction, approximately 249 million metric tons (MMT) of hazardous waste was generated in the U.S. Of this, approximately 47 MMT or 19.0 percent could have been disposed of by incineration. However, only a fraction was actually managed this way. The Congressional Budget Office (CBO) (10) estimated that 2.7 MMT was burned in 208 incinerators. A 1981 EPA study (11) estimated that approximately 3.8 MMT of hazardous waste was disposed in over 1300 industrial boilers and furnaces. A more recent survey (12) indicates that approximately 900 boilers and 45 to 55 industrial furnaces are currently burning hazardous waste as fuel. The 1981 and 1983 information are combined in Figures 2 and 3 which gives a graphical representation of hazardous waste generation and thermal disposal. As can be seen, it is estimated that approximately 14 percent of the incinerable waste is managed by incineration and in industrial boilers and furnaces as fuel.

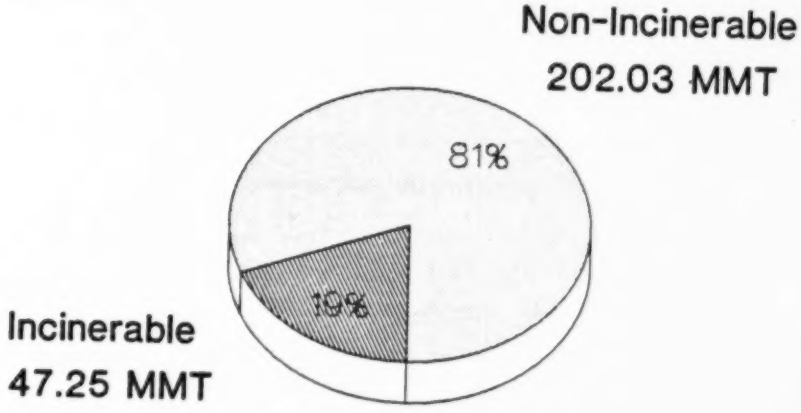

Figure 2. Estimated HW Generated in the US.

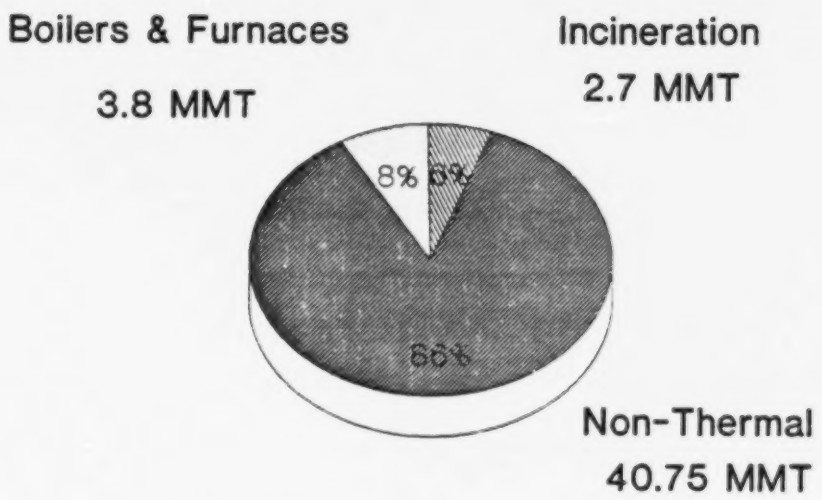

Figure 3. Incinerable HW Actually Incinerated.

INCINERATORS

Five types of hazardous waste incinerators are currently utilized. They are:

1. Liquid injection
2. Hearth (Controlled air)
3. Fluidized bed
4. Rotary kiln (Including afterburner)
5. Fume

In order to meet Federal and State emission standards, these systems are usually equipped with devices to control particulates, hydrogen chloride, chlorine, sulfur oxides and other emissions. However, units burning non-chlorinated wastes with little or no ash content may not. The APCE which is downstream of the final combustion chamber and energy recovery equipment will usually consist of one or more of the following devices:

1. Quench chamber
2. Particulate collection device
3. Gas-absorbing device
4. Mist eliminator

Data Source

This paper examines incinerator performance data from two sources:

1. EPA study of 8 incinerators (13).
2. Trial burn data submitted to EPA by 14 RCRA permit applicants(2).

The EPA study was conducted between 1982 and 1984. Typically, operating conditions during the tests were normal as determined by the plants. However, in some cases carbon tetrachloride and trichlorethylene were

spiked into the wastes if not already present to allow cross comparability to other tests. Table 1 gives a distribution of the incinerator types and control devices encompassed by the EPA study.

Table 2 gives a distribution of the incinerator types and control devices represented by the 14 RCRA applicants.

Table 1. DISTRIBUTION OF INCINERATOR TYPES AND CONTROL DEVICES IN EPA'S EIGHT-SITE STUDY*

Item	No. of Facilities**
Incinerator Type:	
Liquid injection	8
Rotary kiln	2
Hearth	2
Fume	1
Control Device:	
None	3
HCl scrubber	5
Various particulate controls	4

* Source: Reference No. 2.
**Does not total 8 because some units have multiple incineration capabilities and either particulate or HCl controls or both.

Table 2. DISTRIBUTION OF INCINERATOR TYPES AND CONTROL DEVICES FOR 14 SITES SUBMITTING TRIAL BURN REPORTS*

Item	No. of Facilities**
Incinerator type:	
Liquid injection	7
Rotary kiln	5
Hearth	4
Fume	4
Fluidized bed	1
Control Device:	
None	2
HCl scrubber	11
Various particulate controls	9

* Source: Reference No. 2.
**Does not total 14 because some units have multiple incineration capabilities and either chlorine or particulate controls or both.

Eight EPA Tested Incinerators

Figures 4, 5, 6 and 7 summarize the DRE performance, HCL removal and particulate and CO emissions, respectively for the eight EPA sponsored tests. All values are presented as averages for each facility. Average DREs met the 99.99 percent limit in all cases. However, DREs for individual POHCs contained at 1200 ppm or less in the waste feed did not always meet this limit. The HCl removal met the RCRA limit in all cases except sites 2 and 8 whch had removals of 98.3 percent.

Meeting the particulate emission limit of 180 Mg/M^3 was a significant problem for sites 2 and 6 and emissions from site 5 were slightly over the limit. In some cases salt carry over from caustic scrubbing can end up as particulates and high particulate emissions may not be due to the waste material. In any case these two sites would likely need significant design and/or operational changes to reduce particulate emissions below 180 Mg/M^3. The other five sites met the limit.

While the 1982 incinerator regulations do not specify a CO limit, the RCRA operating requirements stipulate that the permit will. In addition, consideration is being given to setting a CO limit to control PICs as has been proposed for industrial boilers and furnaces. Therefore, the incinerator CO emissions have been analyzed and compared to 100 ppm. CO emissions were less than 100 ppm for 6 of the facilities. Sites 4 and 7 were substantially above this level. However, data for site 4 is not necessarily representative of a well operated incinerator as this facility was intentionally operated with insufficient excess air and below design temperatures. Site 7, a rotary kiln and afterburner, was being batch fed highly volatile waste and the on-site EPA observer believes that based on refactory color observations the afterburner temperature was actually closer to 1600°F compared with the indicated 1800°F. Furthermore, it is believed that operation of the afterburner at 1800°F would have reduced the CO emissions below 100ppm.

Fourteen RCRA Applicants

Figures 8, 9, 10 and 11 summarize the DRE performance, HCL removal and particulate and CO emissions, respectively for the RCRA applicants. As with the EPA tests, all values are presented as averages. Average DREs were above 99.99 percent for all facilities. Also, HCl removal either met or approached the RCRA limit. HCl emissions were less than 4 lb/hr. for sites 2, 6, 7, 8 and 9. HCl removal for the remainder of the sites exceeded 99 percent except for sites 5 and 14 which had removals of 98.6 and 98.4 percent, respectively.

Particulate emissions were a problem for sites 3 and 7 while site 1 was slightly over 180 Mg/M^3. The remainder of the sites were below the RCRA limit. CO emissions were less than 100 ppm for 10 of the sites; however, sites 1, 4, 9 and 12 were substantially above this level.

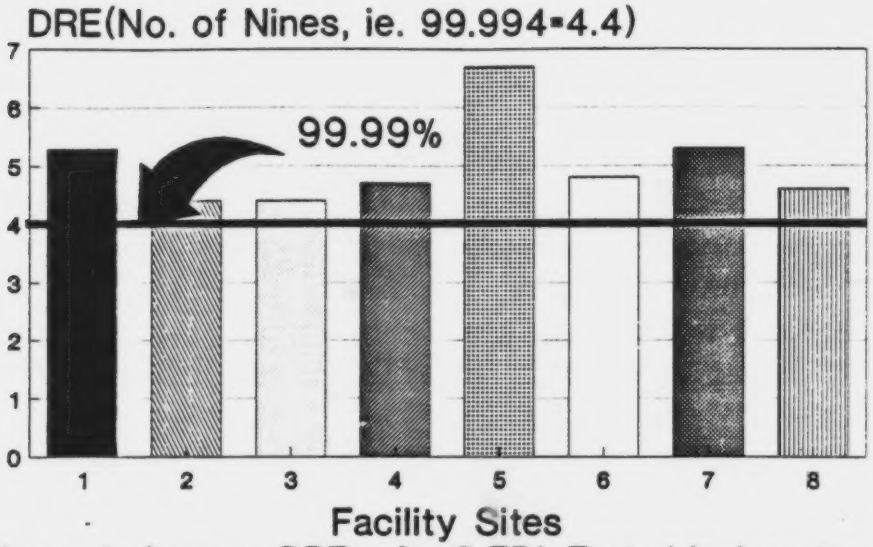

Figure 4. Average DREs for 8 EPA Tested Incinerators.

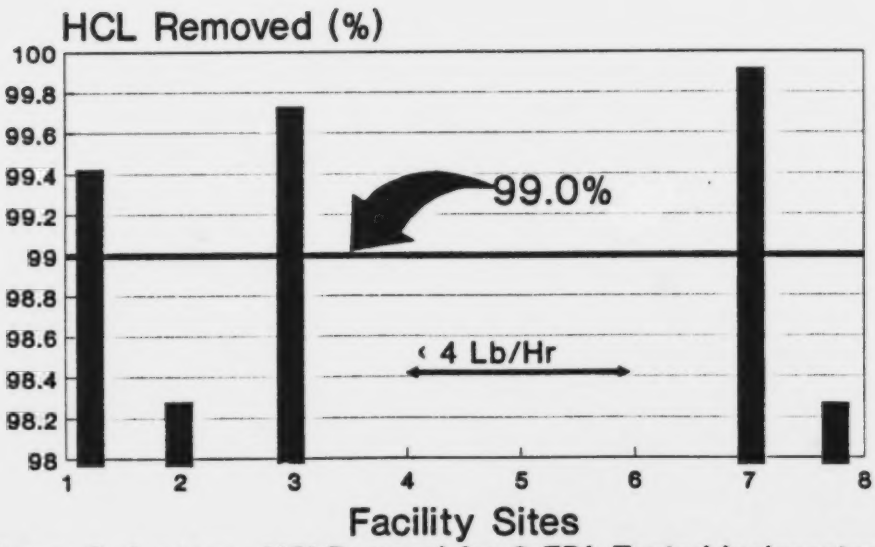

Figure 5. Average HCl Removal for 8 EPA Tested Incinerators

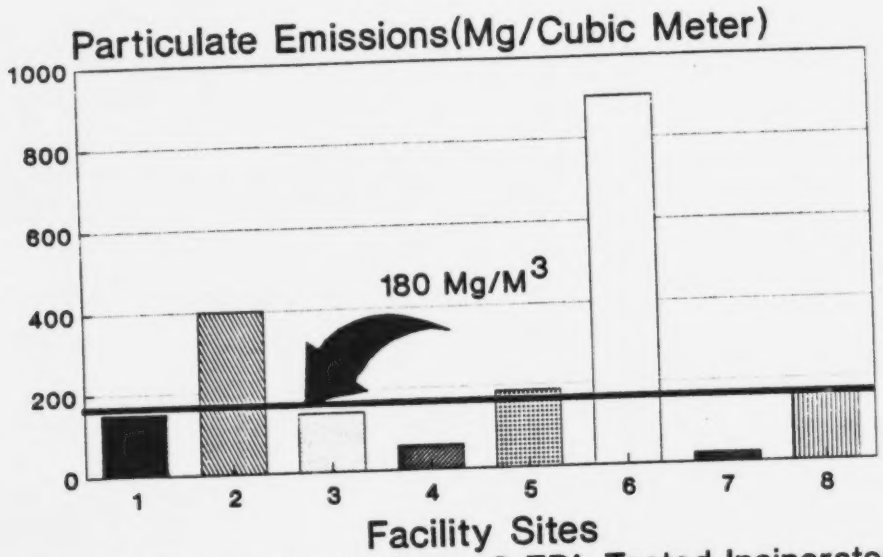

Figure 6. Average Particulates, 8 EPA Tested Incinerators.

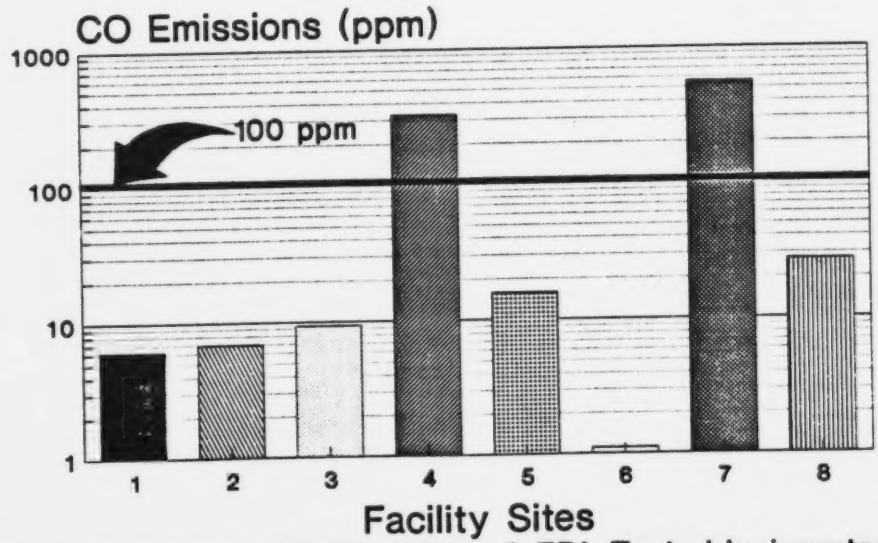

Figure 7. Average CO Emissions, 8 EPA Tested Incinerators.

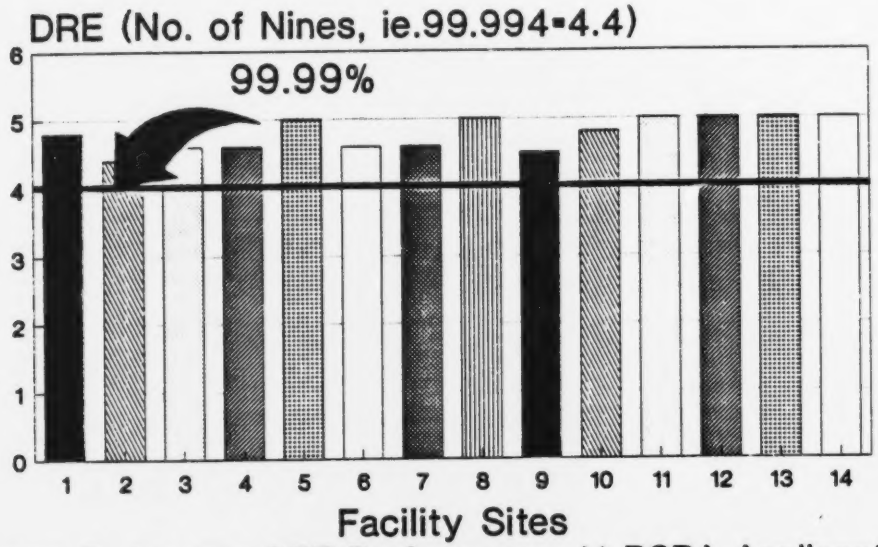

Figure 8. Average DRE Performance, 14 RCRA Applicants.

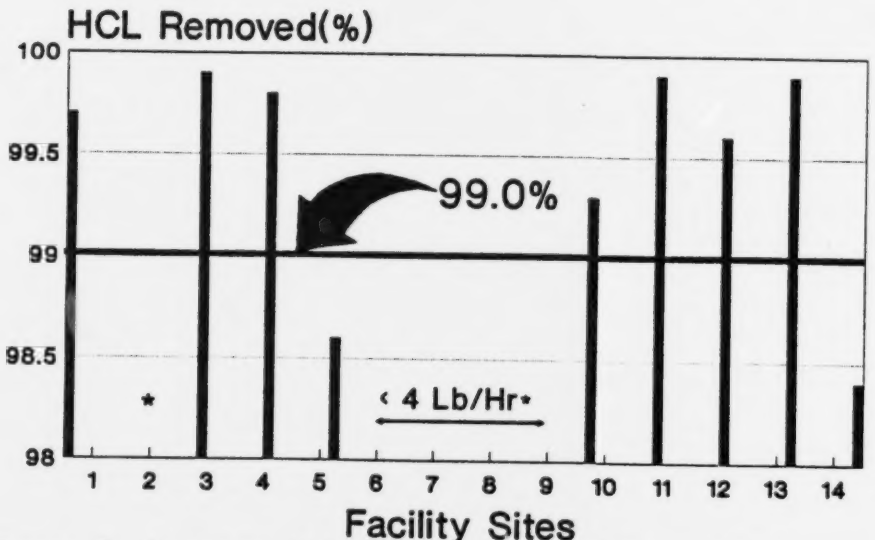

Figure 9. Average HCL Removal, 14 RCRA Applicants.

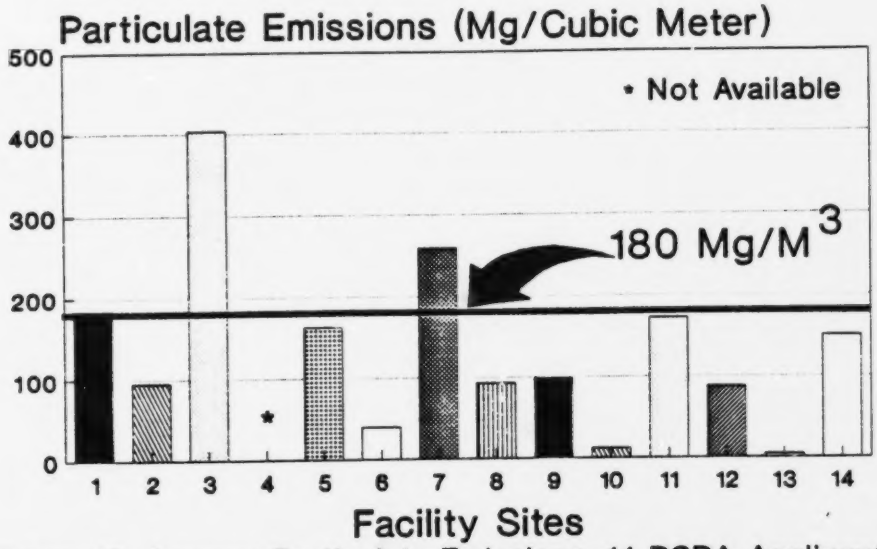

Figure 10. Average Particulate Emissions, 14 RCRA Applicants

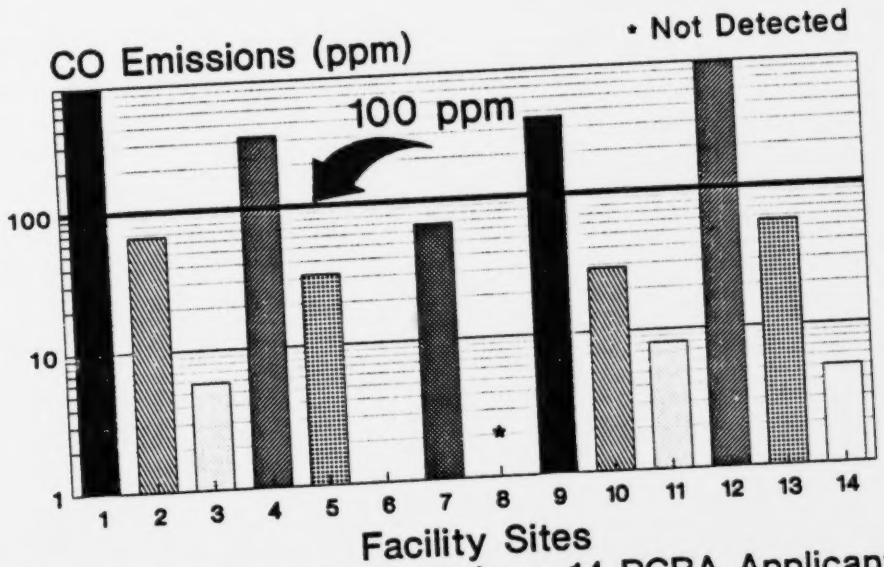

Figure 11. Average CO Emissions, 14 RCRA Applicants.

INDUSTRIAL BOILERS

The main purpose of industrial boilers is to produce steam for process needs. When hazardous waste is burned in a boiler it is usually as a supplementary fuel, although in some cases it may be the sole fuel source. Typically, these wastes are burned with fuel oil or natural gas and provide less than 50 percent of the boiler's fuel requirements. The hazardous wastes are generally organic by-products from chemical manufacturing or spent solvents. The wastes are either generated on-site or by a similar facility, and have heating values that average 10,000 BTU/lb. Usually these wastes contain low concentrations of metals and chlorine. Since most boilers have minimal APCE, the low concentration of potential pollutants is an important criteria for co-disposal.

EPA has conducted field tests on 11 industrial boilers cofired with conventional fuels and hazardous wastes. For the most part, these boilers were tested under normal conditions. Table 3 describes the types of facilities tested and associated pollution control. Figures 12, 13 and 14 summarize the DRE performance and particulate and CO emissions. DREs are presented as averages, while particulate and CO emissions are presented as ranges. The average DREs exceeded 99.99 percent for nine of the sites. Sites A and F were marginally below this value.

Table 3. TYPES OF BOILERS TESTED AND POLLUTION CONTROL

ID Code	Facility Type	Pollution Control
A	Watertube stoker	Multiclone
B	Packaged firetube	none
C	Field erected watertube	none
D	Converted stoker	none
E	Packaged watertube	none
F	Converted watertube	none
G	Modified firetube	2 Scrubbers in Series
H	Tangentially fired watertube	ESP
I	Packaged watertube	none
J	Packaged firetube	none
K	Packaged watertube	none

Although particulate emission limits have not been proposed for industrial boilers and furnaces, available particulate emission data (sites A, D, E, F and G) has been compared to the incinerator limits for discussion purposes. The APCEs and at sites A and G were not effective in reducing particulate emissions to 180 Mg/M^3 as they ranged as high as 360 and 877 Mg/M^3, respectively. Average emissions from sites E and F were consistently below 180 Mg/M^3 and the emissions from site D ranged from 38 to 189 Mg/M^3. Particulate emissions were not determined at the other sites.

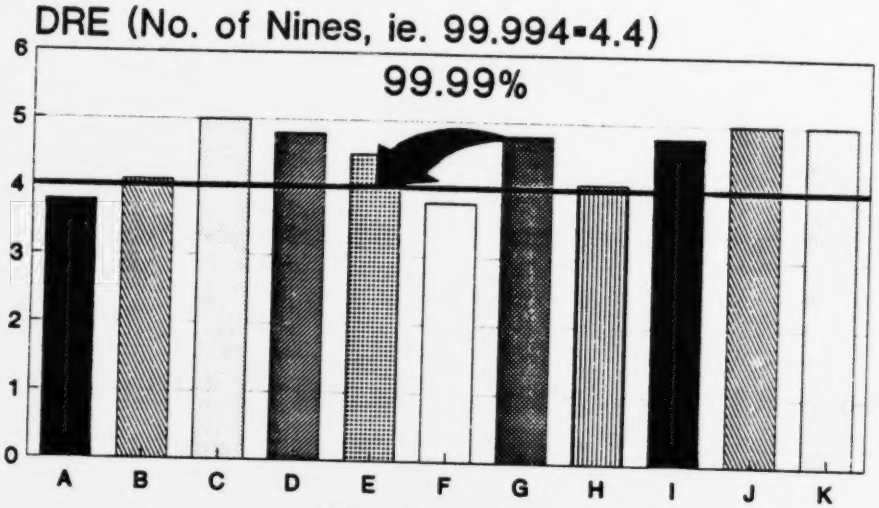

Figure 12. Average DRE Performance for 11 Boilers.

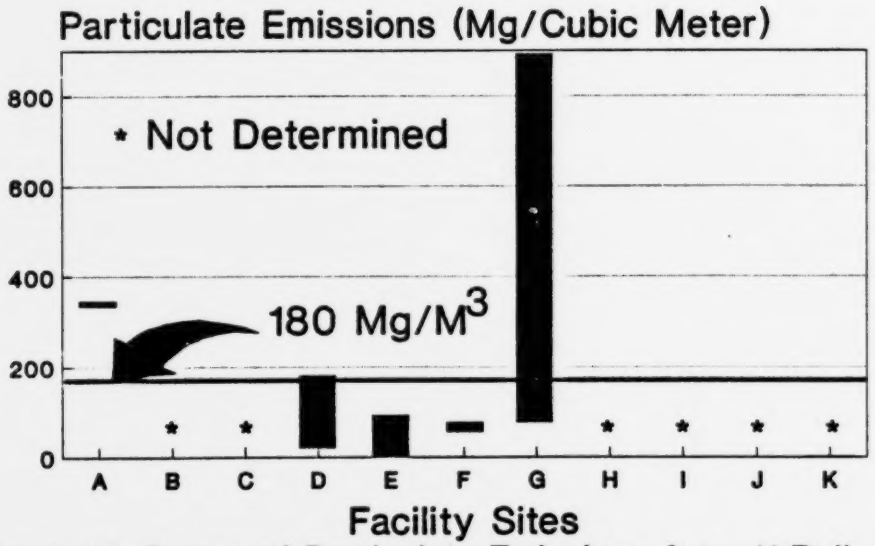

Figure 13. Range of Particulate Emissions from 11 Boilers.

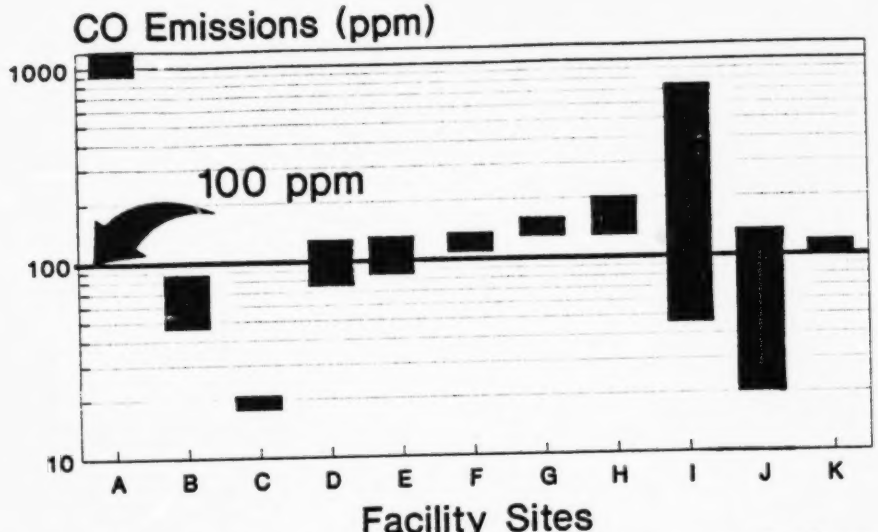

Figure 14. Range of CO Emissions from 11 Boilers.

It appears that most of the boilers would require some equipment or operational modification to meet the proposed CO limit. Only two (sites B and C) had CO emissions that were consistently below 100 ppm. Sites A and I had CO emissions that ranged as high as 1200 and 750 ppm, respectively. Five of the sites (A, F, G, H and K) had CO emissions that were consistently above 100 ppm. HCl emissions were less than 4 lb/hr in all cases since the chlorine content in the waste was low.

INDUSTRIAL FURNACES

EPA defines industrial furnaces as specifically identified enclosed devices using controlled flame combustion to recover (or produce) materials or energy as an integral component of a manufacturing process (8). Furthermore, EPA has designated 11 types of industrial furnaces which are:

1. Cement kilns
2. Lime kilns
3. Aggregate kilns
4. Phosphate kilns
5. Coke ovens
6. Blast furnaces
7. Smelting, melting, and refining furnaces
8. Titanium dioxide chloride process oxidation reactors
9. Methane reforming furnaces
10. Pulping liquor recovery furnaces
11. Combustion devices used in the recovery of sulfur values from spent sulfuric acid

EPA is also proposing to add a twelfth type, halogen acid furnaces.

Unlike boilers, industrial furnaces are usually equipped with APCE and may burn hazardous waste with a chlorine content of 1 to 3 percent and a very high level of metals. Currently, it is known that hazardous wastes are burned in cement kilns and aggregate kilns. In addition, it is believed that sulfur recovery furnaces may burn some hazardous waste and the burning of hazardous waste in lime kilns has been demonstrated through test burns. Also, until recently hazardous waste was burned in blast furnaces by one steel company.

EPA has evaluated the use of hazardous waste as fuel in 8 industrial furnaces (14,15). To the extent possible, normal operating conditions were maintained. In most cases, the waste fuel was spiked with various organic compounds. Table 4 describes the types of facilities tested and associated pollution control.

Table 4. TYPES OF INDUSTRIAL FURNACES TESTED AND POLLUTION CONTROL

ID Code	Facility Type	Atomized Waste	Pollution Control
A	Wet process cement kiln	N	Fabric filter
B	Wet process cement kiln	Y	ESP
C	Dry process cement kiln	N	ESP
D	Dry process cement kiln	Y	Fabric filter
E	Lime kiln	Y	Fabric filter
F	Shale aggregate kiln	Y	Scrubber
G	Clay aggregate kiln	Y	Scrubber
H	Clay products kiln	Y	Fabric filter

Figures 15, 16 and 17 summarize the DRE peformance and particulate and CO emissions. DREs and particulate emissions are presented as averages while CO emissions are presented as ranges. Average DREs met the proposed 99.99 percent limit for all sites except site A which was feeding a non-atomized waste. Particulate emissions from sites A, B, E and H were below 180 Mg/M^3; however, emissions from sites F and G averaged 252 and 227 Mg/M^3, respectively. Particulate data was not available for sites C and D. CO emissions from sites A, B and E ranged substantially above the proposed limit of 100 ppm reaching values as high as 738, 337 and 1357 ppm, respectively. CO emissions from sites C, D and H were consistently below 100 ppm and CO emission data was not determined for sites F and G.

CONCLUSIONS

1. Based on 1981 and 1983 data, only about 14 percent of the incinerable waste is being disposed of by thermal means.

2. The average DRE for all 22 incinerators met or performed better than 99.99 percent.

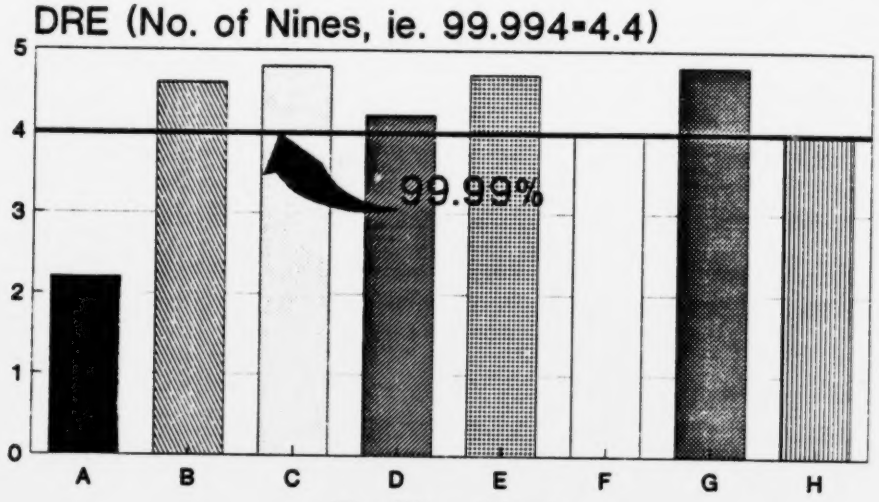

Figure 15. Average DRE for 8 Industrial Furnaces.

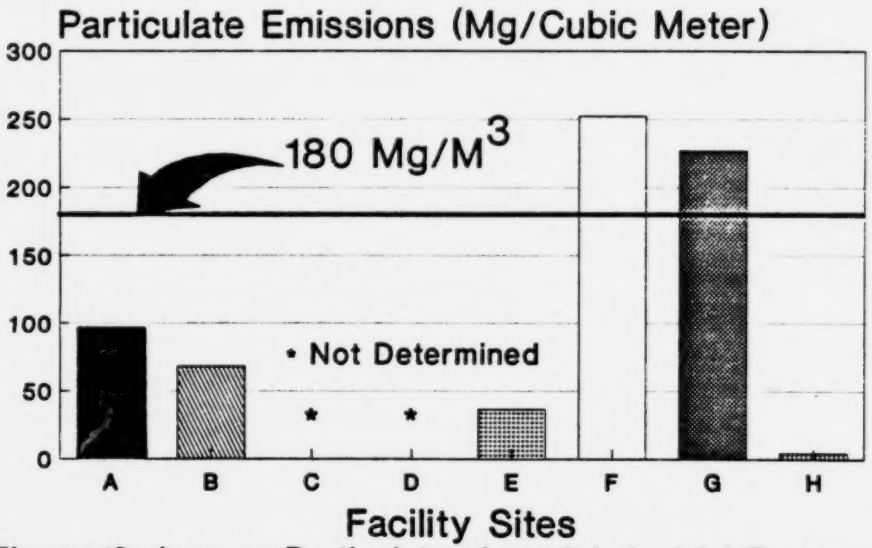

Figure 16. Average Particulates from 8 Industrial Furnaces.

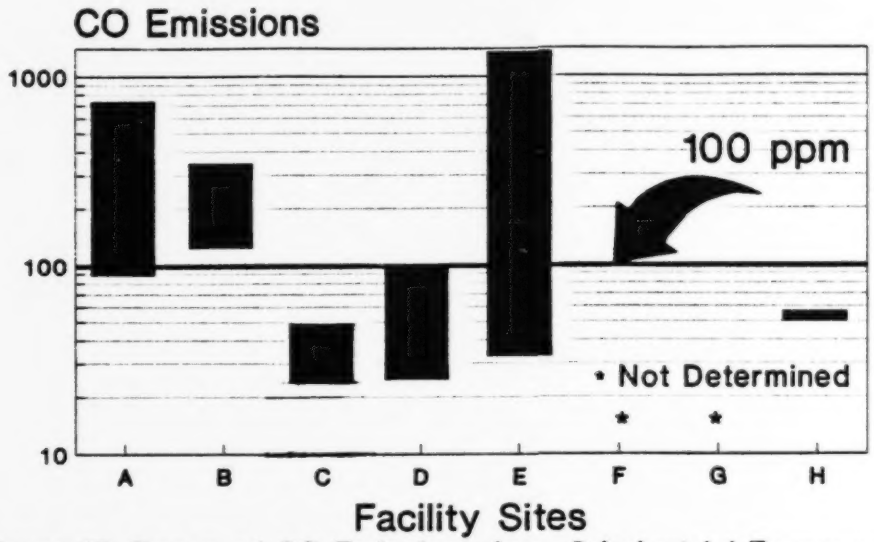

Figure 17. Range of CO Emissions from 8 Industrial Furnaces.

3. The incinerators were able to meet the HCl limit in most cases. However, removals for some facilities were slightly below 99 percent, but could likely meet the standard with minor operating adjustments.

4. While most incineration particulate emissions were below the RCRA limit, some incinerators will likely require significant design and/or operational changes to reduce particulate emissions below 180 Mg/M^3.

5. CO emissions for most of the incinerations were below 100 ppm. However, emissions for some were substantially above this level.

6. Nine of the eleven boilers had average DRE's of 99.99 percent or better. Two were slightly below this level.

7. Particulate emission data was only available for 5 of the 11 boilers and indicated that certain facilities may require some modification, if particulate emission limits are established.

8. It appears that most of the boilers studied would require some equipment or operational modifications to meet a CO limit of 100 ppm.

9. All industrial furnaces feeding atomized waste achieved an average DRE limit of 99.99 percent.

10. Some industrial furnaces may require operational and/or equipment modification, if further particulate limits are established.

11. CO emissions ranged substantially above 100 ppm for three of the industrial furnaces indicating some modifications would be required to reduce these emissions to 100 ppm.

LITERATURE CITED

1. Scott Bronstein, "Laying Waste to Landfills", The Atlanta Constitution, A-1, June 8, 1988.
2. U.S. EPA, "Permit Writers Guide to Test Burn Data - Hazardous Waste Incineration", EPA-625/6-86/012, September 1986.
3. E.T. Oppelt, "Incineration of Hazardous Waste - A Critical Review, JAPCA, Vol. 37, No. 5, pg. 558-586, May 1987.
4. U.S. EPA, "Standards Applicable to Owners and Operators of Hazardous Waste Treatment Facilities", Federal Register, 47(122, Part V): 27516-27535, June 24, 1982.
5. U.S. EPA, "Hazardous Waste Management System: Identification and Listing of Hazardous Waste," Federal Register 45 (98, Part III): 33084-33137, May 19, 1980.
6. Federal Register, Vol. 51, No. 151, Pg. 28305-28310, August 6, 1986.
7. U.S. EPA, "Dioxin Rule", Federal Register, January 14, 1985.
8. U.S. EPA, "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Destruction in Commerce, and Use Prohibition", Federal Register, 44, 31514, May 31, 1979.
9. Federal Register, Vol. 52, No. 87, pg. 16962-17050, May 6, 1987, 40 CFR Part 260 et al.
10. U.S. Congress, Congressional Budget Office, "Hazardous Waste Management: Recent Changes and Policy Alternatives," U.S. Government Printing Office, 1985.
11. U.S. EPA, "National Survey of Hazardous Waste Generator and Treatment, Storage and Disposal Facilities Regulated Under RCRA in 1981," U.S. Government Printing Office, 055000-00239-8, 1984.
12. WESTAT, Final Report for the Survey of Waste as Fuel: Track II, November, 1985.
13. U.S. EPA, "Performance Evaluation of Full-Scale Hazardous Waste Incineration," 5 Volumes, NTIS, PB85-129500, November 1984.
14. U.S. EPA, "Draft Summary Report on Hazardous Waste Combustion in Calcining Kilns", March 1985.
15. U.S. EPA, "Evaluation of Hazardous Waste Incineration in Aggregate Kilns," February 1985.